QuanTalks

IISc Quantum Technology Initiative (IQTI) Seminar Series

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at 4.00 PM (IST)
Physics Department
Auditorium, IISc

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Title: New topologies and ferroelectric phases in epitaxial multiferroic bismuth ferrite thin films

Abstract: Complex oxide thin films and superlattices provide an exciting playground for exploring and fine-tuning structure-property relationships. By playing with the electrical and mechanical boundary conditions through epitaxial strain, substrate orientation, and superlattice design, completely new phases of these materials – with enhanced or new functionality – are possible. In piezoelectric oxides, for instance, tuning the morphotropic phase boundary by strain offers a route to generating improved electromechanical responses. At the same time, there has been increasing interest in ferroelectric solitons – topologically protected particle-like polarization textures with great promise for beyond-CMOS technologies – which can form in ferroelectric oxide thin films through the competition among various degrees of freedom. However, while polar skyrmions have been extensively studied (e.g., in the PbTiO3-SrTiO3 (STO) system), such polarization textures have scarcely been demonstrated in multiferroics.

In this talk, we show that epitaxial strain and orientation engineering, as well as careful control of mechanical and electrical boundary conditions through superlattice design, can be used to craft new phases and topological textures in the popular multiferroic BiFeO3 (BFO). First, using "anisotropic epitaxy" (i.e., growing epitaxial films on extremely vicinal substrates) we create a low-symmetry phase of BFO that acts as a structural bridge between the rhombohedral-like and tetragonal-like polymorphs. Interferometric displacement sensor measurements reveal that this phase has a 2.4x enhanced piezoelectric coefficient compared with typical rhombohedral-like BFO.

Second, by combining BFO with STO in carefully designed superlattices, we demonstrate ferroelectric solitons in this popular multiferroic system. High-resolution piezoresponse force microscopy and Cs-corrected high-angle annular dark-field scanning transmission electron microscopy uncover a zoo of topologies, and polarization displacement mapping of planar specimens reveals center-convergent/divergent topological defects as small as 3 nm. Phase field simulations reveal that some of these structures can be classed as "bimerons" with a topological charge of ±1, and effective Hamiltonian computations show that the coexistence of such structures can lead to non-integer topological charges, a first observation in a BiFeO3-based system. Our results once again highlight the versatility and power of epitaxy for the creation of novel phases in oxide thin films, and open new opportunities in multiferroic topotronics.

Biography: Nagarajan (Nagy) Valanoor received his B. Engg in Metallurgy from the University of Pune (1997) and Ph.D. from the University of Maryland (2001) under the supervision of Prof. Ramesh in Materials Science and Engineering respectively. Following his Ph.D. he continued as a research associate at Maryland until 2003. He followed this with an Alexander von Humboldt Fellowship with Prof. Rainer Waser at Forschungszentrum Juliech. In 2005 he was offered a lectureship at the School of Materials Science and Engineering, where he is currently Professor and Postgraduate Coordinator. He has built, from scratch, a world-class suite of facilities at UNSW in the areas of nanofabrication, thin film synthesis, and atomic scale measurements. The total number of his peer-reviewed (listed on ISI Web of Science) publications is >200 including publications in Science, Science Advances, Nature Materials, Advanced Materials, Nano Letters, Nature Communications, and ACS Nano.

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